Evaluation of Low-Cost Solutions to Support Flight Operations Quality Assurance

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Summary of impact

The work, completed in collaboration with a flight safety group in the UK involved the evaluation of portable 'black box' flight data recorders to support a Flight Operations Quality Assurance (FOQA) program (continuous safety improvement) using simulated flight data. The novel approach involved the use of a commercial flight simulator and pilot proficiency checks to generate simulated flight data at zero cost and zero risk. The work has shown that such portable solutions can provide useful flight (safety) data. In addition, it has also been demonstrated that Electronic Flight Information Systems can also provide useful data in support of a FOQA program. The work has encouraged operators to take up FOQA on a voluntary basis where this is not mandated by regulatory bodies, contributing to continuous safety improvement.

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Abstract

During the period 2003~ 2011 worldwide accident rates for business/corporate aviation were nearly four times that for commercial aviation. Flight Operations Quality Assurance or Flight Data Monitoring - the collection of real-time flight data for continuous safety improvement - has been routinely used by commercial aviation for over 50 years. Regulatory authorities only require airplanes over 27 tonnes Maximum Take-off Weight to operate a Flight Operations Quality Assurance Program . Corporate/business aviation operators generally operate airplanes less than 20 tonnes using a diverse range of airplanes which may include a single engine, twin engine, turbo-prop and/or very light jets. This study investigates the use of low-cost, independent Commercial-off-the-shelf technologies utilising a combination of Global Positioning Systems and Attitude Heading & Referencing Systems to sense and record key flight data parameters in support of a Flight Operations Quality Assurance program for corporate operators with diverse, lower weight category and legacy airplanes. The preliminary results suggest that such systems and Electronic Flight Information Systems (where installed) can usefully support a Flight Operations Quality Assurance for lower weight category and legacy airplanes.

I. Nomenclature

h	=	height above ground level [feet]
kts	=	knots
φ	=	bank angle [deg]
σ	=	standard deviation

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II. Introduction

Worldwide fatal accident rates for the period 2003~ 2011 for business/corporate aviation were nearly four times that for commercial aviation [1]. The 5-year totals for accident rates from 2009~2013 by phase of flight for Business Aviation airplanes [2] shows that 19.1% of accidents for business jets take place in the take-off & climb and 66.4% in the approach & landing. Similarly, 18% of accidents for turboprops occur in the take-off & climb and 64.3% in the approach & landing (Fig. 1).

Flight Operation Quality Assurance (FOQA)/Flight Data Monitoring (FDM) - the collection of real-time flight data for continuous safety improvement - has been commonly used by commercial airlines for 50+ years [3] and more recently in rotary wing operations [4]. Currently, regulatory authorities only require airplane over 27 tonnes Maximum Take-off Weight to operate a FOQA/FDM program [5]. FOQA/FDM is recommend but not mandatory for airplanes between 20~27 tonnes and optional for lower weight categories. Corporate/business aviation operators generally utilise airplanes less than 20 tonnes using a diverse range of airplanes which may include a mix of single engine, twin engine, turbo-prop and/or very light jets. The absence of mandatory requirements, lack of Flight Data Recorders (FDRs) and lack of digital flight instruments in legacy airplanes means that flight data is not readily available to support FOQA/FDM.

Operators with modern fleets and higher weight category airplanes utilise Quick Access Recorders (QARs) to collect flight data, these units linking directly to the airplane's FDR or digital data bus.

These airborne Digital Flight Data Recorders (DFDRs/SSFDRs) are designed to provide quick and easy access to raw flight data, using USB or cellular network connections and/or the use of standard flash memory cards. QARs typically sample 60+ flight data parameters at frequencies ranging from 0.25 Hz (e.g. engine pressure ratios) to 8 Hz (e.g. accelerations).

This study highlights key results with respect to the feasibility of using Commercial Off The Shelf (COTS) technologies such as Lightweight Airplane Recording Systems (LARS) utilising a combination of Global Positioning Systems (GPS) and Attitude Heading Referencing Systems (AHRS) to sense and record key flight data parameters in support of an FOQA/FDM program for corporate operators with diverse, lower weight category and legacy airplanes [6], [7]. These are completely stand-alone units with built-in sensors (AHRS + GPS) capable of recording data to removable media and may use an internal or external power supply. In the USA, these devices commonly referred to as LARS may be crash-resistant but not usually crashworthy since their primary purpose is to collect data in support of an FDM program.

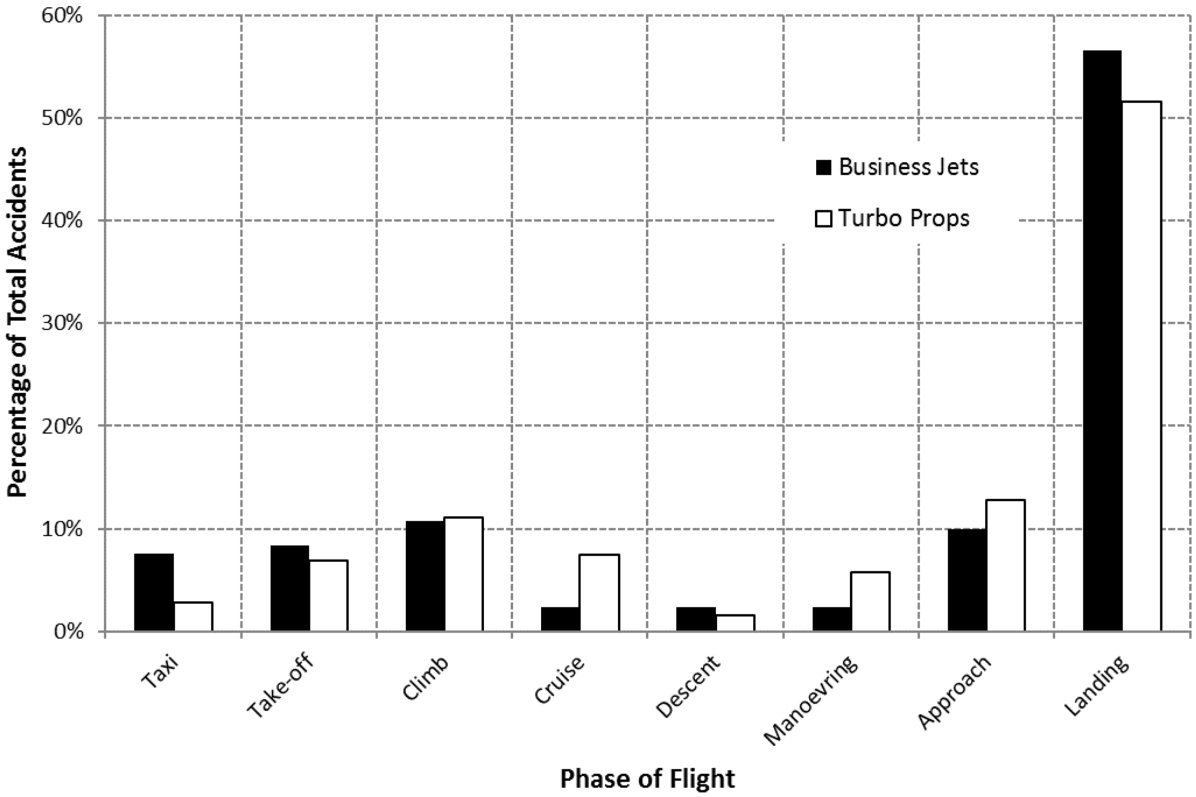

Fig. 1 Business Aviation Accidents for USA from 2009 to 2013 by Phase of Flight - Adapted from [2]

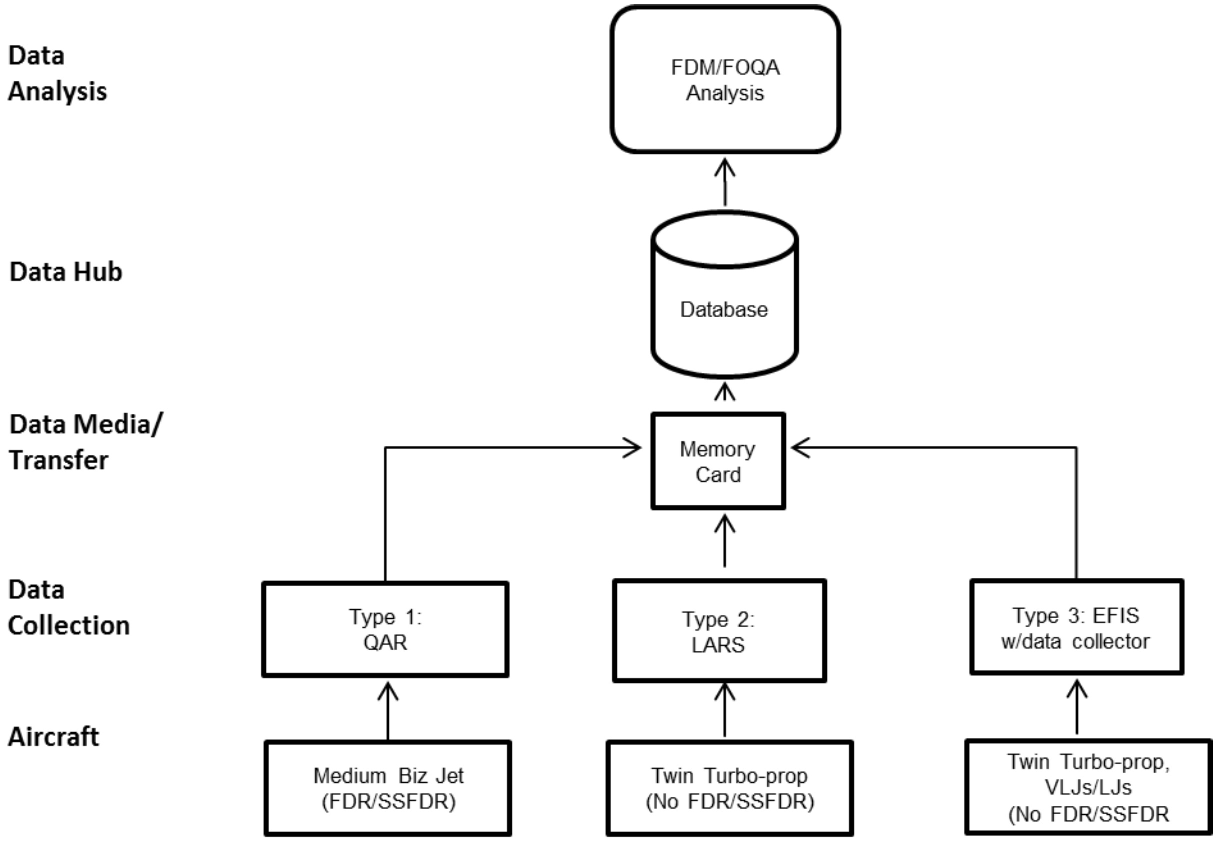

Fig. 2 FDM/FOQA/FOQM and Data Recording Device Types – Adapted from [6]

Data Parameters & Event Triggers

Typical FDM systems are pre-programmed with up to 200 events, defined through years of operational experience and are specific to an airplane make/model and/or operational environment. Statistics are used to analyse this operational data to determine the normal and off-nominal ranges and limits for given events. Airline policy and Standard Operating Procedures (SOPs) in combination with the FDM system capabilities are used to define the expected operations limits [8]. For example, a ‘High Bank Angle below 500 ft above ground level (AGL)’ event would require two key data parameters to test for limit exceedance: the bank angle and height above ground level. The associated ranges and limits for the bank angle are normal, low, medium or high severity (Table 1). Tuning the event thresholds so that they represent ‘near normal’ distribution is key (Fig. 3). A change in SOPs should be reflected in the FDM events list and limits so as not to generate ‘false positives’ (an event is falsely detected) or ‘false negatives’ (an event is missed altogether).

Table 1, Example Event - Criteria and Associated Limits

					Limits/confirmation times		
	Monitoring window				**Severity**		
Event	**Start**	**End**	**Criteria**	**Units**	**Low**	**Med**	**High**
High Bank Angle below 500 ft	Approach Phase and AGL <= 500 ft	Approach Phase end	|Roll| >=	deg	10	15	20

Fig. 3, High Bank Angle on Approach Event Limits & Severity

Recording Device Accuracy and Precision of Results

The precision and accuracy of data recording devices vary with how each parameter is sensed (initially analogue), how it is converted to digital form, and how it is stored in digital form. Selected, additional parameters may also be derived from base level parameters e.g. (Table 2).

Table 2, Comparison of Data Precision/Accuracy by Device Type

Device Type	Parameter	Units	Sampling Rate (Hz)	Stored as	Storage Medium	Precision	Static Accuracy (typical)
QAR	Bank Angle	deg	2	12-bit word (0 - 4096)	PCMCIA Card	0.0879	+/- 0.5 deg 3σ
LARS	Bank Angle	deg	4	Double precision floating point number	SD Card	0.0100	+/- 1.5 deg 1σ
EFIS	Bank Angle	deg	1	Double precision floating point number	SD Card	0.0100	+/-1.25 deg 1σ

Data Sensing to Recording

For large commercial airplanes, sensors onboard measure analogue data parameters such as bank angle and these data are converted to digital (binary) form using an analogue-to-digital converter (ADC) (Fig. 4). Data is then transferred to the airplane onboard computers and shared via the airplane data bus with the flight data acquisition unit and made available to the onboard airplane systems such as Electronic Flight Information Systems (EFIS), where installed. The flight data acquisition unit (FDAU) aggregates binary data for different parameters in a specific sequence and transmits the data to the flight data recorder with a copy sent to the quick access recorder (where fitted) for more convenient access. The sequence in which parameters are aggregated is defined by the data frame which is specific to the airplane type and equipment fitted. The data frame or logical frame layout describes all the parameters recorded, along with associated data allowing binary data to be retrieved together with position in the frame, recording frequency and resolution. The data frame definition is also used to decode binary data from the quick access recorder post-flight. Flight data recorders store data in ‘words’ with each word comprising 12 ‘bits’ (0 to 4096). This word is used to record one or more parameters and each parameter is by word/bit number. The words can be grouped into subframes representing one second of data and subframes are typically comprised of 64 to 1024 words. The number of bits used to record a parameter depends upon the operational range and required accuracy and one or both may be increased by using several words for a single parameter as necessary. For example, to record bank angle with a theoretical range from minus 180 degrees (bank left) to plus 180 degrees (bank right), 10 bits would enable recording at resolution of $360/2^{10} = 0.3512$ degrees. When higher precision is required an additional 2 bits may be added to enable recording at $360/2^{12} = 0.0879$ degrees.

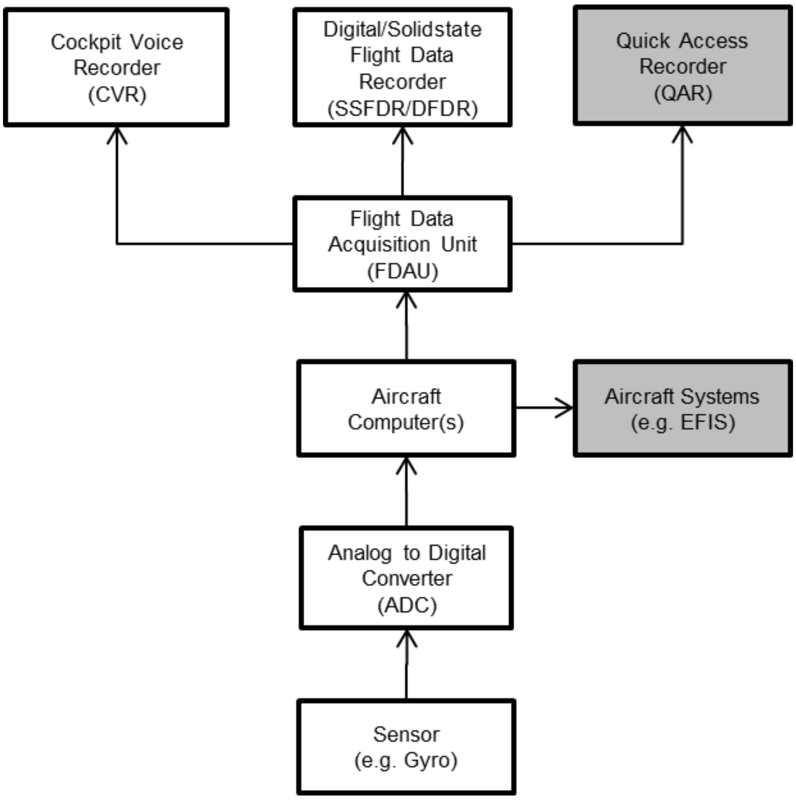

Fig. 4, Data Flow – Sensor to Recorder(s)

III. Method

Previous studies by the Corporate Aviation Safety Executive (CASE) members into the effectiveness of QARs to support FOQA/FDM for business aviation utilised practical flight trials with a single data collector (QAR) installed on a limited number of airframes [9]. With each airframe used by different operators in different environments this approach generated different flight data and generated different safety events. This approach was considered impractical for the comparative assessment of the effectiveness of different types of data recording since the number and type of safety events is unpredictable and disparate within an uncontrolled environment. Therefore, simulated flights were proposed and these were to be conducted in a commercial flight simulator to generate consistent flight and safety event data in a controlled environment.

The initial intention was to append these evaluation flights to recurrent flight checks for participant pilots on a voluntary basis using additional simulator time incurring additional cost. However, preliminary discussions with the simulator operator, flight instructors and FDM specialists, suggested that routine Licence Proficiency/Operator's Proficiency Check (LPC/OPC) flights might also generate the required data thus avoiding additional time or incurring additional cost. A detailed examination of the LPC/OPC tasks indicated that several safety events were likely to be generated due to the nature of the scenarios and required pilots' actions. These events included abnormal and emergency procedures such as take-off with simulated engine failure, rejected take-off, Traffic Collison Avoidance System (TCAS) advisory and engine fires etc.

Having established the suitability of simulated flights (LPCs/OPCs), four flights were conducted in a Gulfstream G550 Full Flight Simulator to generate safety events in a controlled environment. Ethical guidelines and procedures were followed and all data was anonymised by the simulator operator. Using the simulator data logging function, 86 flight data parameters were recorded at a frequency of 8 Hz for the duration of all simulated flights. The recorded, simulated flight data was exported in comma separated (*.CSV) file format and then down-sampled as required to emulate 3 different types of data collection devices (QAR, LARS and EFIS) at representative sampling rates using a defined methodology (Fig. 5). For the QAR, down-sampled data rates varied from 0.25 to 8 H z depending upon the variable type as required by the Federal Aviation Administration (FAA) [10]. For example, 2nd order variables such as (Normal) Acceleration are typically measured at 8 Hz whereas 1st order variables such as Engine Pressure Ratio are typically measured at 0.25 Hz. For the LARS down sampled data rates, all variables were defined at 4 Hz and for the simulated EFIS all data rates were 1 Hz. A full list of parameters and sampling rate for all simulated devices is given in the Appendix.

These data were then converted into required formats for upload into a commercial FOQA/FDM analysis package. FOQA/FDM analysis packages typically accept data defined in Logical Frame Layouts (LFL) [11]. These layouts are data maps that describe the format used to transcribe data to a recording device. The LFL documents details where each bit of data is stored. Even though standardised by airplanes manufacturers, the LFL may change in response to new regulatory requirements, resulting in different LFLs on airplanes of the same type and also vary with the available onboard systems and databus. Regulations on the parameters to be recorded only relate to the DFDR, however they also impact QAR data since this data is generally a copy of DFDR data [10, 12, 13, 14].

All QAR/DFDR data is stored in digital (binary) format. Hence analogue data is converted to digital data in binary format e.g. Angle of Attack (AoA). The FDAU aggregates this binary data for different parameters in a specific order and then transmits the resultant data to the recorder. The sequence which parameters are aggregated is defined by the data frame, specific to an airplane's type and installed equipment. A data frame describes all the parameters recorded, along with associated data allowing retrieving the binary, and then the original value: the position in the frame, the recording frequency, the resolution, the unit, etc.

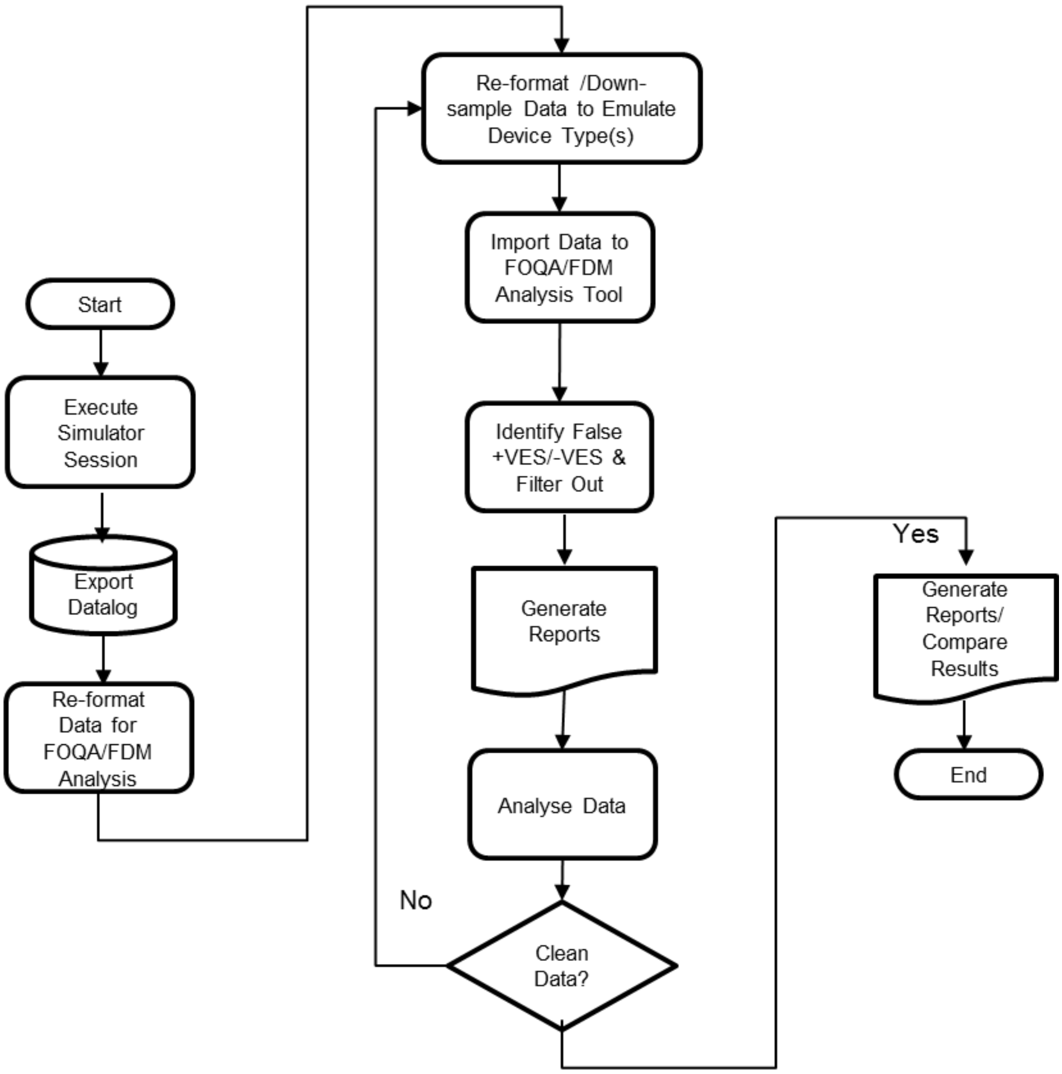

Fig. 5 Methodology for Data Extraction & Analysis

Using the LFL definition, the binary data can be decoded from the recorder. The QAR was used as the experiment 'baseline' sampling 86 parameters at 0.25 to 8 Hz, the LARS using GPS/AHRS sampling 16 parameters at 4 Hz and EFIS (with assumed data export facility) sampling 49 parameters at 1 Hz. The simulator data was collected during four separate simulator sessions of 2~4 hours during LPC/OPCs conducted by four different commercial pilots. In accordance with ethical procedures, data was de-identified and not presented or discussed with instructors or pilots.

The simulator sessions (LPCs/OPCs) comprised a series of pre-planned exercises including normal and emergency procedures to evaluate line/operator proficiency. This provided a means of generating research data without incurring the significant costs of FFS hire with cooperation of the simulator operator. Instructors introduced additional tasks to satisfy the requirements of the LPC/OPC as deemed appropriate. Parts of the LPC/OPC were repeated during the simulator sessions to meet the objectives of the LPC/OPC.

IV. Experimental Results

The commercial FOQA/FDM analysis package included 200+ defined safety events in total across all phases of flight. The number of safety events detected was dependent upon the sensing and recording capability of each device type (Table 3). For example, the 'baseline' QAR (86 parameters) was capable of detecting all events in 6 different categories (as defined by the analysis package), these ranging from accelerations to configurations and warnings. Neither the EFIS (48 parameters) nor LARS (16 parameters) were capable of sensing configurations or warnings. The EFIS system with access to pitot/static data was capable of sensing and recording air data.

Table 3, Sensing/Recording Capability by Device Type

	QAR Type 1	LARS Type 2	EFIS Type 3
No. Parameters	86	16	48
Sampling Rate(s)- Hz	0.25~8	4	1
Accelerations	X	X	X
Attitude/Heading	X	X	X
Flightpath	X	X	X
Air Data	X		X
Configurations	X		
Warnings	X		

For the four given simulated flight scenarios and simulated sensing/recording capabilities for all 3 devices, the preliminary results (Table 4 & Fig 6) show that when compared to the QAR as a 'baseline', the simulated EFIS system detected 43.8% of all safety events across all flights/phases using 49 parameters sampling at 1 Hz. The simulated LARS detected 22.9% of safety events across all flights using 16 parameters sampling at 4 Hz only during the take-off & climb and approach & landing phases of flight.

Table 4, Summary of Number of Events/Types by Phase of Flight & Device

Event Type/Phase	QAR Type 1	LARS Type 2	EFIS Type 3
Acceleration	**1**		**1**
Ground	1		1
Attitude	**34**	**15**	**25**
Air	3		3
Landing & Approach	10	2	9
Take Off & Climb	21	13	13
Configuration	**6**		
Air	1		
Landing & Approach	4		
Take Off & Climb	1		
Flight Path	**28**	**7**	**8**
Air			
Landing & Approach	28	7	8
Take Off & Climb			
Speed	**8**		**5**
Ground	1		
Landing & Approach	7		5
Take Off & Climb			
Warnings	**19**		
Air	1		
Landing & Approach	15		
Take Off & Climb	3		
Grand Total	**96**	**22**	**39**
Using QAR as a 'baseline'	**(100%)**	**(22.9%)**	**(40.6%)**

Table 5, Summary of Number of Events by Phase of Flight & Device

Phase of Flight	QAR Type 1	LARS Type 2	EFIS Type 3
Air	5	0	3
	(100%)	(0%)	(60%)
Ground	2	0	1
	(100%)	(0%)	(50%)
Landing & Approach	64	9	23
	(100%)	(14%)	(36%)
Take Off & Climb	25	13	12
	(100%)	(52%)	(48%)
Grand Total	**96**	**22**	**39**
Using QAR as a 'baseline'	**(100%)**	**(22.9%)**	**(40.6%)**

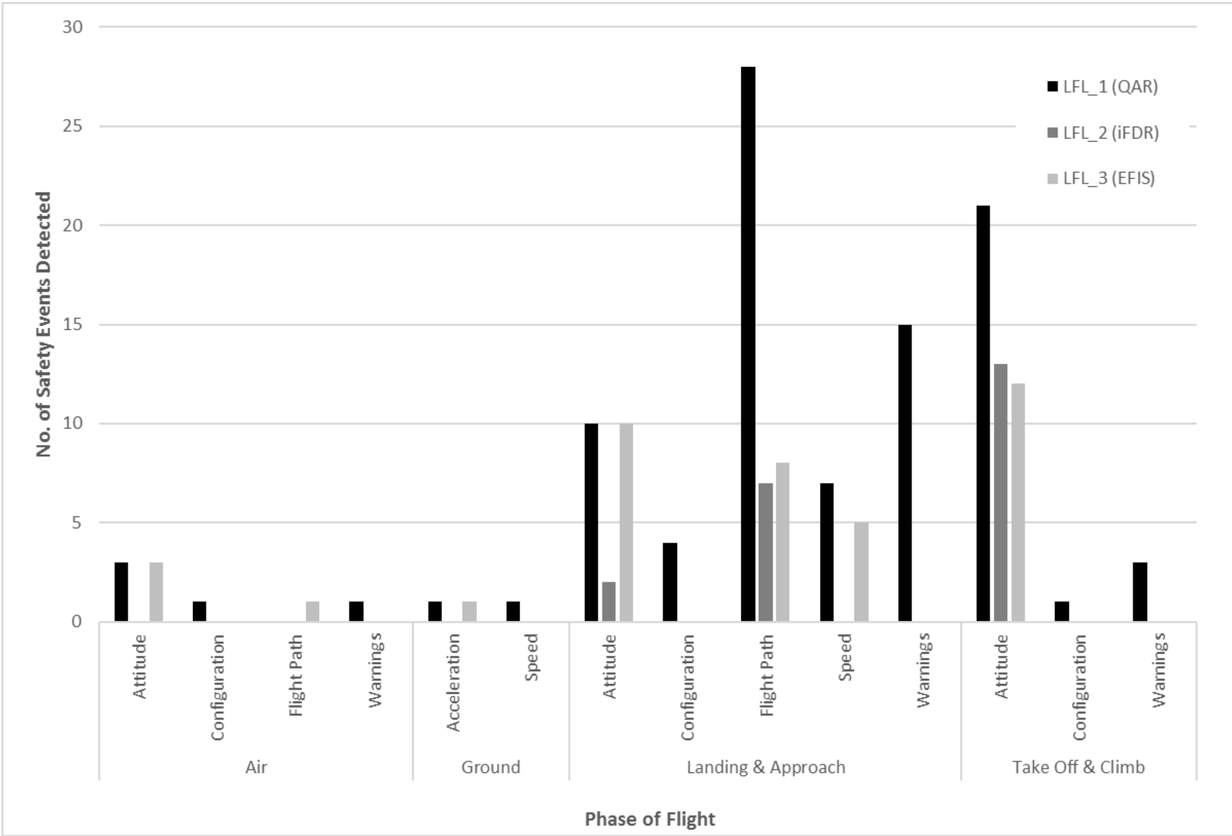

Fig 6 Summary of No. Safety Events Detected by Type & Phase of Flight and Device Type (All Simulated Flights)

V. Discussion of Results

The results show that when compared to the QAR as a 'baseline' (assuming 100% of generated safety events detected) the EFIS system detected almost twice (40.6%) the number of safety events detected by the LARS (22.9%). The lower detection rate of EFIS systems when compared to QAR was due the lack of configuration and warning parameters combined with the lower sampling rate of the device emulated (1 Hz). The lower detection rate of LARSs when compared to QARs was due to the lack of air data (airspeed, pressure height etc.), configuration and warning data. During the analysis of data, it was found that 'false positive' and 'false negative' events were present.

The 'false positive' events detected were related to airspeed and configuration events and were mainly related to the LARS and EFIS. They were triggered by the use of fixed/dummy values of selected parameters such as flap setting and air/ground switch etc. as these data are not sensed/recorded by either of these device types but are required (and expected) by the commercial FOQA/FDM analysis system to identify and confirm flight conditions/phases. In addition, the lack of airspeed for LARS resulted in the substitution of airspeed with ground speed incurring differences due to the effects of wind speed. False positive events were also generated for the simulator device and QAR device and these were due to discontinuities in the (simulated) flight data. Examiners/instructors frequently re-position the airplanes to perform and/or repeat tasks as part of the LPC/OPC checks and as such flights do not follow the normal sequence of flight phases (e.g. taxi, take-off, climb, cruise, descent etc.). These discontinuities are not normally present in routine FOQA/FDM.

Analysis of the data showed that the QAR 'missed' several events ('false negatives'). Upon further investigation it was found that key parameters such as pitch angle, rate of climb/descent, wind speed/direction and stick pusher activated (ON/OFF) were inadvertently omitted from the emulated QAR definition (Appendix A). These parameters would normally be included in the definition of the QAR LFL and are required for complete analysis by a FOQA/FDM system. Pitch is always present, climb or descent rates are either recorded or derived, and wind speed/direction are usually recorded but not essential to FDM and stick shaker/pusher are always recorded. In order to facilitate valid comparisons between the QAR (as a baseline) and the other devices (iFDR and EFIS), events undetected by the QAR (17 in total) were excluded from all devices. The inclusion of these missing parameters in the QAR definition, would increase the number of detected safety events for the QAR and therefore the results for emulated QAR devices are understated herein. In addition, the slower sampling rates used for roll angle (2 Hz) compared to pitch angle (4 Hz) for QAR, may also account for the missing event 'excessive bank on take-off'.

For expediency in the analysis, selected recorded data parameters for each simulated device (QAR, LARS and EFIS) were assumed have equal precision and accuracy, however in reality, precision and accuracy vary with how each parameter is sensed (initially analogue), how it is converted to digital form and how it is stored in digital form. Further analysis should be conducted with attention to different levels of precision, accuracy, signal noise and error rates using mathematical modelling.

Notwithstanding these limitations, the preliminary results are encouraging and suggest that EFIS systems with an appropriate data parameter set can usefully support FOQA/FDM programs. Although LARSs are limited in capability, the identification of safety events in the take-off & climb and approach & landing phases may assist operators in preventing future accidents in these phases of flight. Further, detailed analysis of the safety event data may provide insight into possible enhancements for EFIS data capture and the extended application of LARSs and this analysis will be the subject of a future technical paper.

VI. Conclusions

The study has evaluated 3 different types of data collection devices (QAR, LARS and EFIS) and the number, frequency, precision and accuracy of recorded flight data parameters has been established. Each device type has been successfully emulated using simulated flights generating sufficient detectable safety events for valid comparison.

For the tests and simulated devices using a commercial FOQA/FDM analysis solution it has been shown that the emulated LARS is capable of detecting up to 22.9% of safety events in all phases of flight, 55% of events in the take-off & climb phases of flight but only 14% in the landing and approach (the most safety critical phases of flight[2]). The extension of the basic parameter set (16 parameters) by the use of data derived from the basic set and use of supplementary data such as wind speed/direction and terrain etc., may enhance device capabilities and further investigation is recommended.

In contrast, EFIS systems where installed, offer broader capability at no additional cost, detecting 41.7% of safety events in all phases of flight, 48% in take-off & climb and 36% in landing and approach due to the availability of additional parameters (e.g. air data and real-time weather information). The addition of configuration and warning information to EFIS systems could further enhance capabilities in support of FOQA/FDM programs for Business Aviation.

In summary, fitted EFIS systems used for data collection in support of a FOQA/FDM program for Business Aviation airplanes less than 20 tonnes MTOW may offer several advantages over the LARS solutions, these being lower cost and ability to detect almost twice the number of safety events as the LARS solution in all phases of flight. That said, LARSs enable basic FOQA/FDM capability for data collection for legacy airplanes where EFIS systems are not installed and data is not normally available.

It has been demonstrated that the use of flight simulation and LPC/OPC data (at no cost) can be used as an effective means in the evaluation of COTS technologies in support of a FOQA/FDM program and this method may be extended to other devices using an existing data set. The method has potential to reduce the time required to complete a manual desktop evaluation of a new airplanes introduced to the fleet and a practical means by which to evaluate the newly defined LFLs using simulated flight data representative of that which will be present in normal and abnormal flight operations.

Appendix

Parameters/Sampling Frequency by Device Type

PARAMETER/SAMPLING FREQ. (Hz)	Simulator	QAR Type 1	LARS Type 2	EFIS Type 3	Units	Notes
Timestamp	8	8	4	1	sec	
Calibrated_Airspeed	8	1		1	knot	
Groundspeed	8	1	4	1	knot	
Pressure_Altitude	8	1	4*	1	foot	LARS = GPS Altitude
AAL	8	1			foot	
Runway_Length	8				foot	
Radio_Altitude	8	2			foot	
Magnetic_Heading	8	1	4	1	deg	
Indicated_Mach_Number	8	1			Mach	
Pitch_Angle	8	4	4	1	deg	
Roll_Angle	8	2	4	1	deg	
Yaw_Angle	8	1	4		deg	
Outside_Air_Temperature	8	1		1	degC	
Gear	8	1			%	
Flap_Lever	8	1			%	
Flap	8	1			%	
Spoiler_Lever	8	1			%	
Spoiler	8	1			%	
Spoiler_2	8	1			%	
Spoiler_3	8	1			%	
Spoiler_4	8	1			%	
Spoiler_5	8	1			%	
Spoiler_6	8	1			%	
Spoiler_7	8	1			%	
Spoiler_8	8	1			%	
Angle_of_Attack	8	1			deg	
Pitch_Rate	8	4	4		deg/s	
Roll_Rate	8	2	4		deg/s	
Yaw_Rate	8	1	4		deg/s	
Weight	8	1			lb	
Normal_Acceleration	8	8	4	1	ft/s^2	
Longitudinal_Acceleration	8	2	4		ft/s^2	
Lateral_Acceleration	8	2	4	1	ft/s^2	
Engine_#1_Pressure_Ratio	8	0.25		1	%	
Engine_#2_Pressure_Ratio	8	0.25		1	%	
Reference_Speed	8	1			knot	
Reference_Speed_With_Current_Flap	8	1			knot	

Air_Ground	8	2				
EGPWS	8	1				
Stick_Shaker	8	1				
Stick_Pusher	8					Missing from QAR LFL
Master_Warning	8	1				
TCAS_Warning_Vertical_Speed	8	1		1		
TCAS_Warning_Climb_Climb	8	1		1		
TCAS_Warning_Climb_Climb_Now	8	1		1		
TCAS_Warning_Climb_Crossing_Climb	8	1		1		
TCAS_Warning_Clear_Conflict	8	1		1		
TCAS_Warning_Descend_Crossing_Descend	8	1		1		
TCAS_Warning_Descend_Descend	8	1		1		
TCAS_Warning_Descend_Descend_Now	8	1		1		
TCAS_Warning_Increase_Climb	8	1		1		
TCAS_Warning_Increase_Descent	8	1		1		
TCAS_Warning_Monitor_Vertical_Speed	8	1		1		
TCAS_Warning_Maintain_Vertical_Speed_Cros	8	1		1		
TCAS_Warning_Maintain_Vertical_Speed_Main	8	1		1		
TCAS_Warning_System_Test_Fail	8	1		1		
TCAS_Warning_System_Test_OK	8	1		1		
TCAS_Warning_Test	8	1		1		
TCAS_Warning_Traffic_Traffic	8	1		1		
TCAS_Warning_Test_Complete	8	1		1		
TCAS_Warning_Test_Track	8	1		1		
TCAS_Warning_Test_Lost	8	1		1		
TCAS_Warning_Test_Dropped	8	1		1		
Latitude	8	1	4	1	deg	
Longitude	8	1	4	1	deg	
Glideslope	8	1			dot	
Localiser	8	1			dot	
GPS_Altitude	8		4		foot	Missing from EFIS LFL
Vertical_Speed	8		4	1	ft/min	
Altitude_Above_Mean_Sea_Level	8		4*	1	foot	LARS = GPS Altitude
Track	8			1	deg	
Track_for_Test_Output	8			1	deg	
Engine_#1_Fuel_Flow	8			1		Missing from QAR LFL
Engine_#2_Fuel_Flow	8			1		Missing from

						QAR LFL
Engine_#1_Oil_Temperature	8			1	degC	
Engine_#2_Oil_Temperature	8			1	degC	
Engine_#1_Oil_Pressure	8			1	psi	
Engine_#2_Oil_Pressure	8			1	psi	
True Airspeed	8			1	knot	
Course	8			1	deg	
Windspeed	8			1	knot	Missing from QAR LFL
Wind_Direction	8			1	deg	Missing from QAR LFL
Elevator_Position	8				deg	
Port_Aileron	8				deg	
Starboard_Aileron	8				deg	
Rudder_Deflection	8				deg	
Total Number of Parameters	**86**	**65**	**16**	**49**		

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